Nurses, Pagers, and Patient-Specific Criteria: Three Keys to Improved Critical Value Reporting

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At LDS Hospital, we have developed and evaluated a computerized critical value reporting system based on digital pagers. Criteria used to identify critical values are patient-specific. An evaluation of the system was conducted from October 23, 1993 to January 21, 1994. Results showed that 100% of all critical values (497 values in the form of 335 alerts) were reported to clinicians within an average of 38.6 minutes, and that 51% of all alerts were received within 12 minutes. Data also showed that 92% of the alerts were considered valid, that 76% were communicated directly to the primary care nurse, and that 67% of the time nurses were previously unaware of the critical value(s).

INTRODUCTION

The reporting of critical laboratory test values is an important function of the clinical laboratory and is part of requirements for laboratory accreditation by both the College of American Pathologists and the Joint Commission on Accreditation of Healthcare Organizations (JCAHO). Because critical values indicate life-threatening conditions in patients, it is crucial that they be communicated to clinicians in an effective and timely fashion so that patients can receive optimal care. However, the effective communication of critical values often relies on factors which are not under the laboratory's direct control.

A study of critical value reporting at LDS Hospital identified a number of weaknesses in the reporting process.[1] Among these were 1) that critical values were not always reported by the clinical laboratory, 2) when critical values were reported, it was often to someone not directly involved in the "critical" patient's care, and 3) documentation of the critical value both by the laboratory and in the patient's chart was incomplete.

To correct these weaknesses, we have now implemented a computerized system which automatically alerts clinicians to the presence of critical laboratory test values by means of patient-specific digital pagers. The system was developed using the capabilities of the HELP medical information system at LDS Hospital[2] and was designed to allow implementation of more sophisticated, patient-specific critical value criteria than had previously been practicable.

One of the challenges faced in developing the computerized critical value reporting system was the development of an effective user interface. The user interface had to encompass both alert feedback (relaying alerts to clinicians) and alert acknowledgement (letting the computer know when a clinician had received an alert). In developing the user interface, we endeavored to take human factors (accessibility, mode of interaction, ease of use, speed, etc.) into account, working closely with clinicians to make the system fit their needs. Following the system's clinical implementation, it was evaluated for effectiveness and to identify areas needing improvement.

METHODS

Background

LDS Hospital is a private 520-bed tertiary care facility which is part of the Intermountain Health Care (IHC) hospital system. The hospital's computer facilities support the HELP medical information system which integrates and manages patient data from throughout the hospital. The computerized critical value reporting system was initially implemented and evaluated on the 48-bed East 8 nursing division at LDS Hospital. This division cares for a diverse mix of urology, oncology, and gynecology patients. Computer terminals are available at each patient bedside and at nursing stations on the division. Nurses use the terminals frequently during the course of patient care for data review and charting.

Until the implementation of computerized reporting, critical value criteria only took into account whether a patient's laboratory test results were abnormally high or low. In general, criteria are established by the laboratory in consultation with the medical staff. All laboratory test results are entered into the laboratory computer, verified, and transmitted to the HELP system. The results are then stored in the

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HELP computerized patient database and are available for review on any terminal within the hospital. Laboratory personnel are responsible for identifying critical values when test results are verified.

Established laboratory practice for critical value reporting is as follows: laboratory personnel, having identified a critical laboratory test result, telephone the appropriate nursing unit (the unit where the "critical" patient is located) and report the value to the nurse caring for the "critical" patient. The time of the telephone call and the identity of the person receiving the call are recorded in the laboratory computer by laboratory personnel. This information, along with the critical laboratory test value, is transmitted to the HELP information system. It is then the responsibility of the person receiving the critical value telephone call to ensure that appropriate action is taken.

Design of the Computerized Critical Value Reporting System

In designing the computerized critical value reporting system, our goal was to develop the most efficient and effective system possible within the hospital's existing computing structure and within existing patient care routines. Initially, the critical value reporting system was modeled on a computerized laboratory alerting system (CLAS) developed and implemented at LDS Hospital in the late 1980's.[3] The basic architecture of CLAS has been retained in the computerized critical value reporting system (CLAS II). Differences between the systems exist in the underlying software, the contents of the medical knowledge base, the method of alert feedback to clinicians, and the design of the user interface. The original CLAS was disabled in the early 1990's because of major software changes within HELP.

Many of the main issues to be addressed in designing CLAS II had to do with the user interface. These included: 1) Who should receive alerts?, 2) To what physical location(s) should alerts be sent?, 3) How should the presence of an alert be signified? and 4) How should receipt of an alert be acknowledged?.

After consulting with nurses and physicians, it was decided to communicate alerts to nurses because of their continuous physical proximity to patients. Having decided to transmit critical value alerts to nurses, it followed that the physical location to which alerts should be sent was the nursing unit where the alerting patient was located. In addition to sending alerts to computer terminals on the appropriate nursing unit, critical value alerts were transmitted directly to nurses via patient-specific digital pagers.

Each nurse on a nursing unit carries a digital pager. Digital pagers are assigned to nurses at the beginning of their shift. Ward clerks are responsible for keeping a current computer record of which nurse is caring for which patient(s) and carrying which digital pager. When an alert is generated, an alert message is transmitted by a direct line from the HELP system to the Data General minicomputer which controls all nursing digital pagers. Based on the alerting patient's room number, the nurse caring for the patient is identified and the alert message is transmitted to that nurse's digital pager.

Though CLAS II could theoretically have fulfilled its reporting function by merely identifying and transmitting alerts, it was important to get some kind of acknowledgement in order to provide documentation of critical value reporting and to ensure that alerts were received. Acknowledgement had the additional advantage of providing the data necessary to evaluate CLAS II's effectiveness and make improvements where necessary.

A nurse acknowledges an alert by going to a computer terminal (in a patient room or at a nursing station) and logging on to the alerting patient (using a function key). This brings up a window on the terminal screen which displays a more complete version of the alert message and gives the nurse the option of acknowledging the alert. At this point the nurse also has the option to review associated laboratory data or to review any alerts (past or present) on the patient.

If an alert is not acknowledged within 15 minutes of its original transmission, it is again transmitted, this time to the digital pager carried by the nursing unit's charge nurse. Alerts continue to be transmitted every 15 minutes, alternating between the primary care nurse and the charge nurse, until the alert is acknowledged or until two hours have elapsed. Unacknowledged alerts continue to be indicated on the computer terminal until 24 hours after the alert was originally transmitted. When an alert is acknowledged, the time of acknowledgement and the identity of the person acknowledging the alert are captured and stored in the patient database.

Additional issues which had to be resolved in designing CLAS II included: 1) how to alert for and acknowledge multiple critical values in a single

laboratory test (generate only one alert and allow acknowledgement of the alerts as a group), 2) how to handle critical values for patients who were discharged or transferred to another nursing division (delete alerts for discharged patients and have alerts follow transferred patients to their new nursing division), 3) what to do for patients generating repeat critical value alerts for successive laboratory tests (only generate repeat alerts if the situation is worsening, not if it stays the same or improves), 4) how to handle alerts when the laboratory transmits the same result to the HELP system multiple times (check each transmitted laboratory result to see if it was previously transmitted and stored in the patient database), and 6) how to handle alerts if a "critical" patient's primary nurse was not assigned a digital pager (send the alert to the charge nurse).

Development of the CLAS II knowledge base

In November of 1992, we conducted a one-week study of critical value reporting at LDS Hospital.[1] Two hundred ninety-four critical laboratory test values were identified during the study period. Of these, only 28 (9.5%) were telephoned to the nursing floor as required by the critical value reporting process. Results of the study were shared with the clinical laboratory in December of 1992, and a follow-up study conducted in January-February 1993 showed that the number of critical values being reported to clinicians had risen to 35%.

In an effort to identify reasons for the low rate of critical value reporting, we interviewed laboratory personnel and members of the nursing staff. From these interviews, it was determined that one reason for the low rate of critical value reporting was the inadequacy of the criteria used to identify critical values. For example, though the clinical laboratory's policy manual states that PTT values over 50 seconds are "critical" and should be reported, many patients with elevated PTT's are receiving heparin therapy for which PTT values of up to 90 seconds are considered therapeutic. Knowing this, the clinical laboratory usually only reports extreme PTT values (PTT > 130 seconds). Though laboratory personnel are aware of the inadequacy of the criteria, they do not in general have access to patient data which would allow them to discriminate between patients who are on heparin and those who are not.

The design of CLAS II overcomes this problem because, rather than relying on laboratory personnel to identify critical values, the critical value criteria are encoded into HELP frames which are automatically activated when laboratory test results are stored in the HELP patient database. This strategy makes all data contained in the computerized patient database available for use in determining whether a given laboratory test result is truly critical.

Table 1. Critical Laboratory Value Criteria

Original Criteria	Revised Criteria
Bilirubin > 12 mg/dl	No change
Calcium <6 mg/dl or >13 mg/dl	No change
Glucose <50 mg/dl or >400 mg/dl	No change
Potassium <3.2 mEq/L or >6.0 mEq/L	No change
CO_2 <12 mEq/L or >40 mEq/L	No change
Magnesium <1.0 mg/dl or >5.0 mg/dl	No change
Phosphorus <1.2 mg/dl or >8.0 mg/dl	Phosphorus <1.5 mg/dl or >5.5 mg/dl
Sodium <120 mEq/L or >155 mEq/L	No change
Hematocrit <20%	Hematocrit < 24%
Hemoglobin <6.5 gms	No change
Platelets <50,000/cmm	Platelets <20,000/cmm or oncology patient and <10,000/cmm
Protime >30 sec or <8 sec	No change
WBC < 3000/cmm	WBC >25,000/cmm or <3,000/cmm if not oncology patient
WBC in CSF >10/hpf	No change
PTT >50 sec	PTT <12 sec or >50 sec if not on heparin or > 90 sec if on heparin
No criteria	Creatine >2.0 mg/dl
No criteria	Amylase >110 U/L
No criteria	GGPT >150 IU/L
No criteria	BUN >35 mg/dl
No criteria	LDH <50 IU/L or >350 IU/L
No criteria	ALT >75 IU/L
No criteria	AST >75 IU/L

Using the original laboratory critical value criteria as a starting point, nurses and physicians caring for patients on the East 8 nursing division were asked to respond to the criteria, suggesting how they could be

improved and informing us of additional criteria they would like to see implemented. Using these suggestions, we developed a revised set of critical value criteria which were specific to patients cared for on the East 8 nursing division. Table 1 shows both the original and revised critical value criteria.

Evaluation of CLAS II

Data on the effectiveness of CLAS II were gathered for a thirteen week period from October 23, 1993 to January 21, 1994. Each time an alert was acknowledged, information on the alerting patient, the type of alert, the time the alert was originally transmitted, the time of alert acknowledgement, the identity of the person acknowledging the alert, and the name of the alerting patient's primary care nurse were sent to a special data collection file. In addition, at the time of alert acknowledgement, nurses were asked to complete a short computerized questionnaire. The questionnaire asked whether the alert was valid, whether nurses had already been aware of the alerting critical value, and whether the acknowledger was the primary nurse, the charge nurse, or another nurse on the nursing floor. Nurses' responses to the questionnaire were stored in the data collection file along with the other information on alert acknowledgement. At the end of the data collection period, data were tabulated and analyzed.

RESULTS

Results of the evaluation of CLAS II's effectiveness in reporting critical values are summarized in Table 2. For each week of the study, Table 2 lists the number of alerts, the number of critical values represented by those alerts, the average alert acknowledgement time (in minutes), the number of alerts acknowledged by the primary care nurse, the number of alerts judged to be valid (by nurses), and the number of valid alerts reporting critical values of which nurses were unaware.

Three hundred thirty-five critical value alerts (representing 497 critical values) were generated during the thirteen week study period. All 335 alerts (100%) were acknowledged. For the thirteen week period, the average acknowledgement time was 38.6 minutes. Fifty-one percent of all alerts were acknowledged within 12 minutes (4.2 min ave.), 81% (270 of 335) were acknowledged within 1 hour, and 95% (318/350) were acknowledged within 2 hours. In general, the average acknowledgement time showed a downward trend over time. Overall, 256 of the 335 alerts (76%) were acknowledged by the primary care nurse. Nurses judged 308 of the 335 alerts (92%) to be valid, and indicated that they were unaware of the critical values reported for 207 of the 308 valid alerts (67%).

Table 2. Data on the effectiveness of CLAS II's computerized critical value reporting (October 23, 1993 to January 21, 1994)

Week	# of Alerts (# of CV's)	Ave. Ack. Time (min)	Prim. Nurse/ Alerts	Valid/ Alerts	Unaware/ Valid
1	14(18)	74.0	6/14*	13/14	7/13
2	31(38)	54.5	16/31*	30/31	16/30
3	21(32)	58.4	12/21*	20/21	14/20
4	26(35)	40.9	15/26*	23/26	16/23
5	24(25)	23.0	19/24*	20/24	13/20
6	27(42)	21.4	24/27@	25/27	18/25
7	17(18)	20.4	16/17@	17/17	15/17
8	27(41)	33.1	18/27@	26/27	20/26
9	19(31)	29.9	16/19@	14/19	8/14
10	37(57)	68.6	31/37@	34/37	21/34
11	39(69)	35.0	37/39@	35/39	19/35
12	24(30)	18.4	23/24@	22/24	18/22
13	29(61)	21.9	23/29@	29/29	22/29
Total	335(497)	38.6	256/335 (76%)	308/335 (92%)	207/308 (67%)

*based on data entered by ward clerks
@based on RN computerized questionnaire responses

DISCUSSION

Because of the life-threatening nature of critical laboratory values, it is important that they are communicated to clinicians within a short period of time. It is for this reason that critical value reporting has become standard practice within the clinical laboratory. Though we recognize the need for careful studies of the effects of computer systems in general, and of computerized alerting systems in particular,[4] it was not our goal to determine what effect CLAS II had on either patient outcome or the patient care process except to determine whether critical value reporting itself had been improved. We believe that CLAS II was successful in doing this since evaluation data showed the average alert acknowledgement time to be 38.6 minutes with 51% of all alerts acknowledged within 12 minutes.

Another measure of CLAS II's effectiveness in communicating critical values to clinicians is how well it compares with other similar computer systems. In recent years, a number of computerized systems have been designed to alert on conditions indicated by laboratory test results. In addition to the original CLAS,[5] two such laboratory alerting systems, one designed to detect critical creatinine values[6] and one designed to detect critical values and trends in ICU patients,[7] have been shown to have a positive impact on patient care.

The original CLAS experimented with several methods of alert feedback including activating a flashing light to indicate the presence of an alert (6 min ave. acknowledgement time), posting alerts on computer terminals (38.7 hr ave. acknowledgement), and integrating alerts with laboratory data review (3.6 hr ave. acknowledgement). Of the two other alerting systems similar to CLAS II, the system implemented at Beth Israel Hospital for reporting critical creatinine values[6] made use of electronic mail to send alerts to physicians (93.7 hrs from time of alert transmission to change in therapy) while the system implemented to detect critical values in ICU patients[7] sent alerts to central nursing station and bedside terminals in the same way the original CLAS did (no data on average acknowledgement time were reported).

Given the fact that the flashing light used in the original CLAS was very unpopular with users and that 51% (170/335) of alerts transmitted by CLAS II using digital pagers were acknowledged in an average of 4.2 minutes, we feel that CLAS II compares favorably with all of the alert feedback methods which have been tried. One of the advantages of CLAS II's use of digital pagers is that nurses can receive alerts in any location within the hospital without having to modify their normal patient care activities. This means that alerts reach the nurses in a more timely fashion, as they do not have to be at or near a computer terminal to receive an alert.

One encouraging result of the evaluation was the fact that 92% (308/335) of the critical value alerts generated and reported by CLAS II were judged to be valid by the nurses receiving them. The 27 critical value alerts judged to be invalid did not, in general, seem to indicate a problem with any particular alert criterion, as most of the different possible critical values were represented only once or twice. These results, along with verbal feedback from the nurses on East 8, satisfied us that the revised set of critical value criteria was adequate. We feel that CLAS II's ability to implement critical value criteria tailored to the specific needs of different patient populations within the hospital not only contributes to the high rate of alerts judged to be valid, but also encourages the rapid acknowledgement of alerts, as they are seen to be a valuable aid in delivering quality patient care.

In summary, data collected during our evaluation of the CLAS II computerized critical value reporting system show that CLAS II is an effective tool for critical value reporting. Because of CLAS II's automatic nature, *every* critical value (100%) is reported. This is a dramatic improvement over the reporting rates found in our earlier studies (9.5% for November 1992, 35% for January-February 1993).[1] In addition, using CLAS II, 76% of all critical value alerts were communicated directly to the nurse responsible for the "critical" patient. By contrast, data collected for January-February 1993 showed that, of 124 critical values, there was *only one* documented instance in which the critical value was reported directly to the primary care nurse. Finally, CLAS II's design ensures that all critical value reporting is well documented by automatically capturing the time a critical value is acknowledged and the identity of the acknowledger.

References

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